# Advanced Fuel Cycle System R&D Activities at KAERI

## - Pyroprocessing and SFR -

May 28, 2014

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# Outline

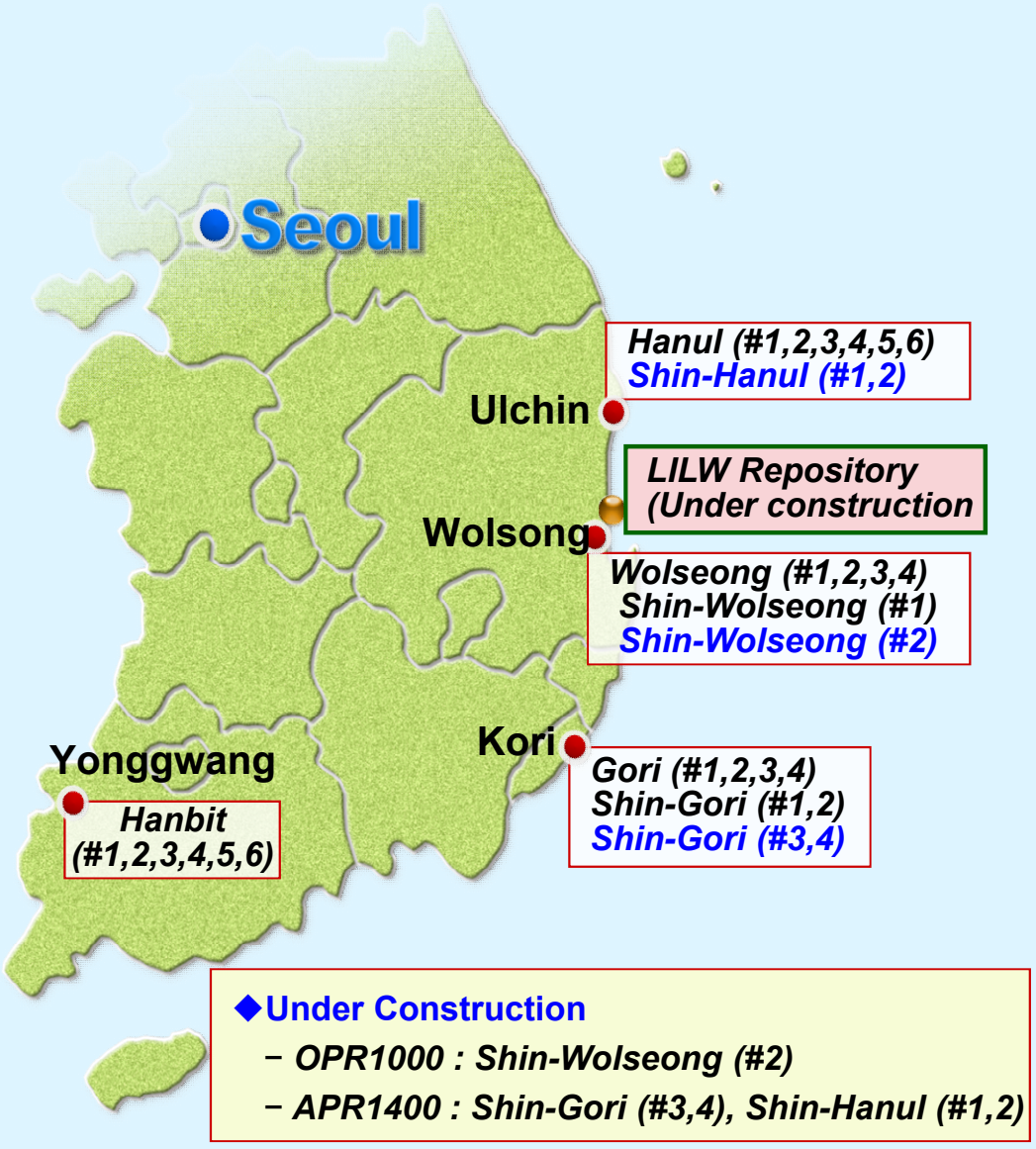
I Status of Nuclear Energy in Korea

II Nuclear Fuel Cycle R&D Programs
: Pyroprocessing and SFR

III Closing Remarks

# Status of Nuclear Energy in Korea

# Nuclear Power Plants in Korea

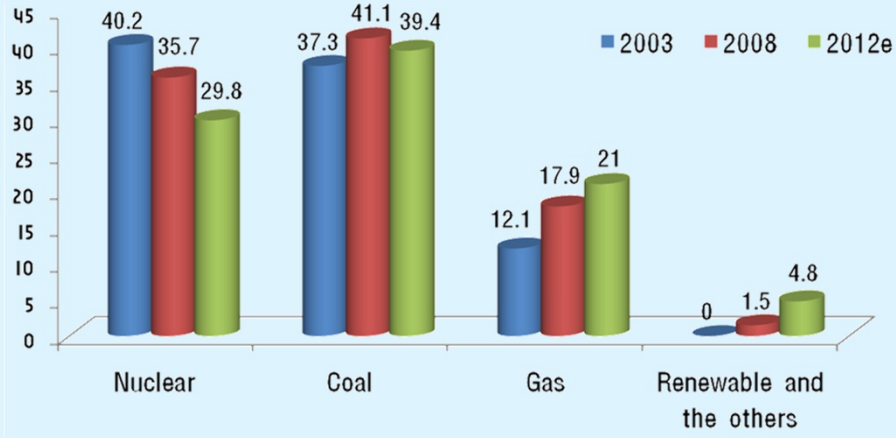



## [Generating Capacity (MWe) as of Mar. 2013]

| Site | In operation | Under Construction | Total (2016) |
|---|---|---|---|
| Gori | 6( 5,137) | 2 (2,800) | 8 (7,937) |
| Wolseong | 5 (3,779) | 1 (1,000) | 6 (4,779) |
| Hanbit | 6 (5,900) | - | 5 (5,900) |
| Hanul | 6, (5,900) | 2 (2,800) | 8 (8,700) |
| Total | 23 (20,716) | 5 (6,600) | 28 (27,316) |

** Source : www. khnp.co.kr*

## [ Ratio of Electricity Generation ]




** Source : www. Kepco.co.kr, # 2012e : estimated*

# Spent Fuel (SF) Generation

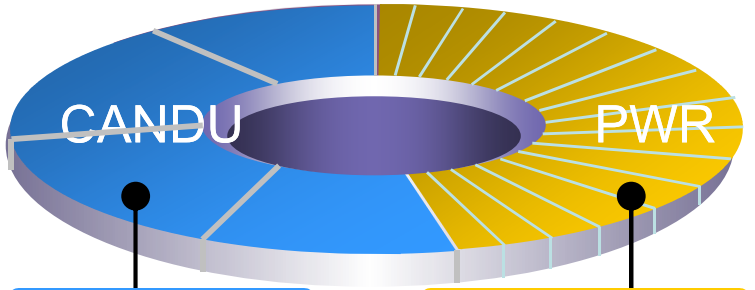
## Current status of SF storage (‘13. 6)

- On-site SF storage limit will be reached in the near future

| Site | Capacity (t) | Current storage (t) | Expected saturation (yr) |
|---|---|---|---|
| Gori (PWR) | 2,691 | 2,035 | 2016 (2026*) |
| Hanbit (PWR) | 3,318 | 2,118 | 2019 (2024*) |
| Hanul (PWR) | 2,328 | 1,790 | 2021 (2025*) |
| Wolseong(CANDU) | 9,660 | 7,005 | 2018 (2026*) |
| Total | 17,997 | 11,328 | |

* Capacity Extension case

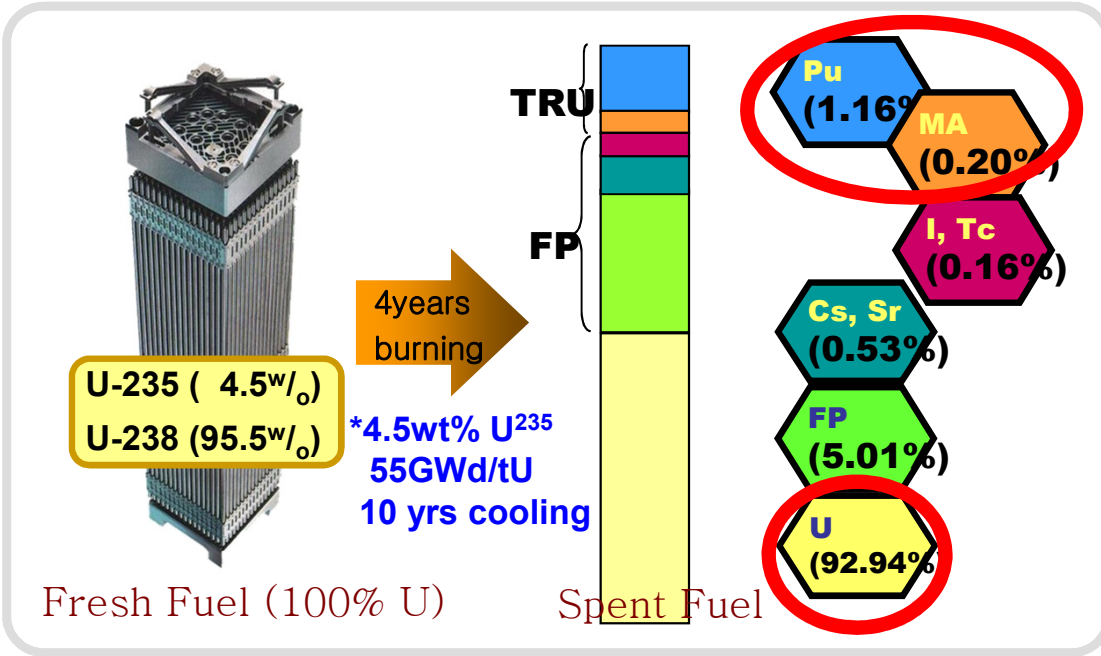
## Annual generation & characteristics




- 95 t/yr,unit
- 4 units
- 380 t/yr

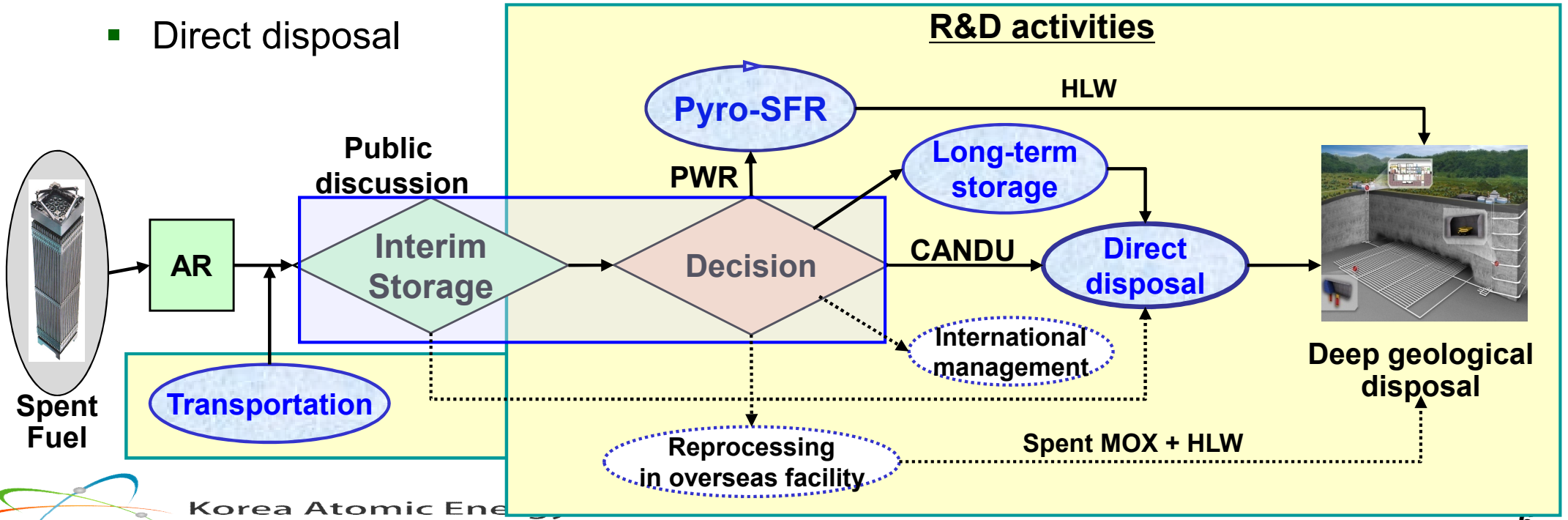
- 20 t/yr, unit
- 19 units
- 340 t/yr

[Annual Generation : 720t/yr]



# Nuclear Fuel Cycle Options for SF Management

- **Public and Stakeholder Engagement Program has been launched**
  - **Mission** : Proposal of basic direction for spent fuel management including interim storage by participating public and stakeholders
- **Spent fuel management policy will be established based on open discussions and public consensus**
  - R&D activities to provide technical information for decision-making
    - Transportation and Long-term storage of spent fuel and associated wastes
    - Pyroprocessing-SFR Closed fuel cycle and Proliferation-resistance
    - Direct disposal

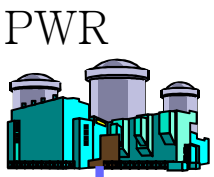


# Nuclear Fuel Cycle R&D Programs

## - Pyroprocessing & SFR -

# Pyro-SFR Fuel Cycle for SF Management

## Reduction of Spent Fuel Disposal Area & Radiotoxicity



PWR

SNF

Interim storage

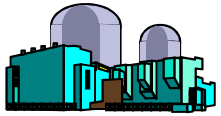
I, Tc

Pyroprocessing

SFR

U, TRU

U-TRU-Zr fuel

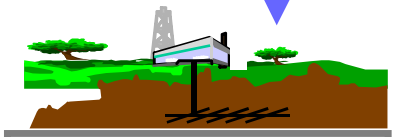


CANDU

SFR

HLW

Cs, Sr



Long-term storage

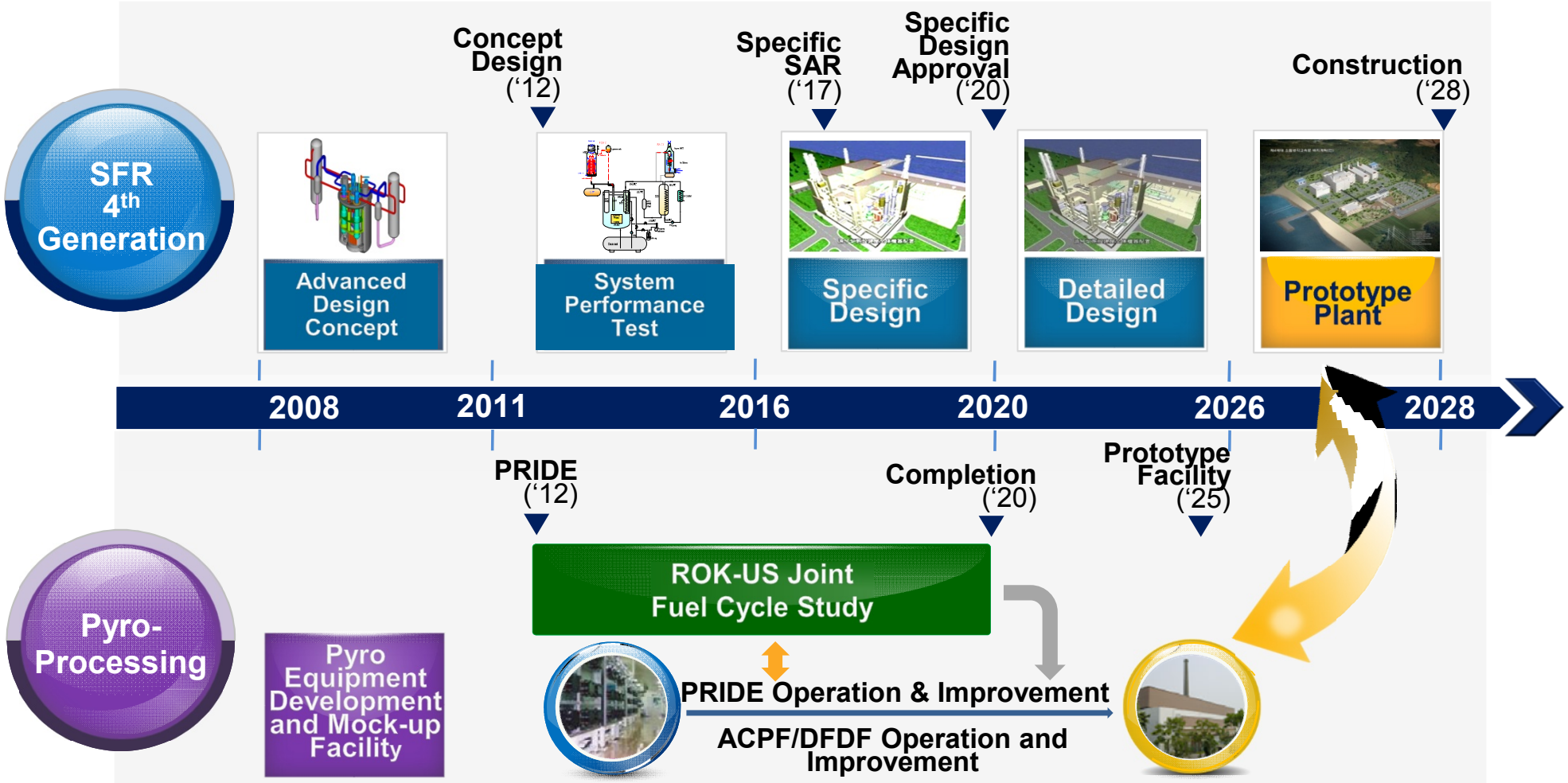
HLW repository

LILW Repository

* TRU (Transuranics) : Pu + MA
* MA (Minor Actinides) : Np, Am, Cm

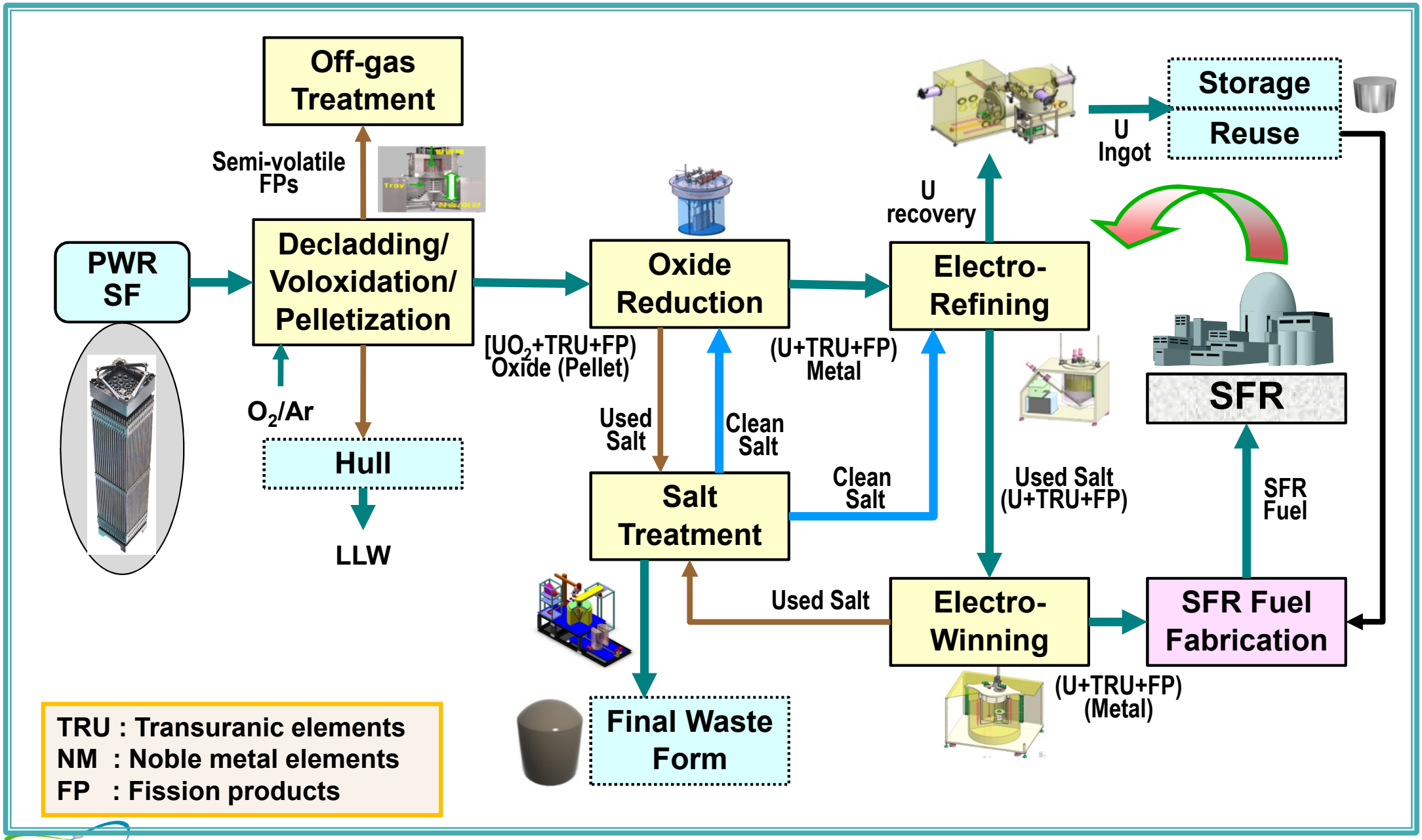
# R&D Plans for Future Nuclear Energy System

- **Long-term R&D plan for Pyro-SFR closed fuel cycle development**
  ***(255th AEC on 2008, 1st AEPC on 2011)***




AEC : Atomic Energy Commission
AEPC : Atomic Energy Promotion Commission

# Flow Diagram of Pyroprocessing



# Pyroprocessing R&D Status

- **Objectives and R&D strategies**
  - **Increasing throughput, process efficiency and scale-up capability**
    - Development of core and leading-edge pyro-technologies by using Lab.-scale equipments
    - Combination of U tests at PRIDE and hot-tests at INL through JFCS*
    - ACPF/DFDF Facilities Operation
  - **Simple / easy remote operability and enhanced inter-connectivity between unit processes**
    - Construction and long-term operation of Eng.-scale PRIDE facility
  - **Reducing high-level waste generation**
    - Waste minimization by FPs separation and salt recycling
  - **Safeguards approach and enhanced proliferation-resistance**
    - PR/PP enhancement and 3S by Design

**Exterior of PRIDE**

**** JFCS : Joint Fuel Cycle Study***

# Pyroprocessing Development

## Recent R&D status (I)

### High throughput

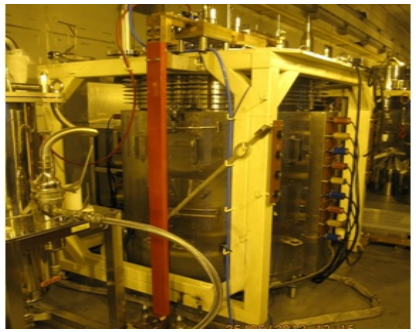
- Suitable feed material fabrication for accelerating electrolytic reduction reaction
- Semi-continuous operation of electrorefiner by adding a bucket-type uranium deposit transfer system
- Self-scraping of U dendrite by application of graphite cathode at electrorefiner

### Process Efficiency

- Group recovery of 99.9% TRU by Residual Actinides Recovery(RAR) process using LCC electrolysis and $CdCl_2$ oxidant

### Scale-up Capability

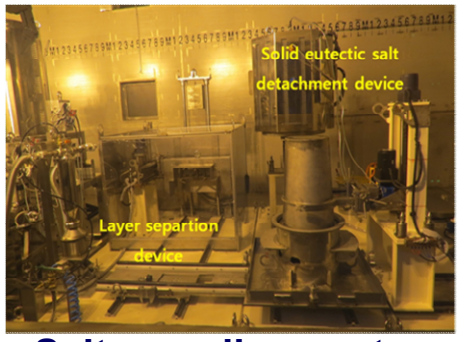
- Design and fabrication of Eng-scale PRIDE based on Lab-scale performances



50 kgU/batch reducer

Refiner with a bucket

RAR for TRU recovery




Salt recycling system

# Pyroprocessing Development – Cont'd

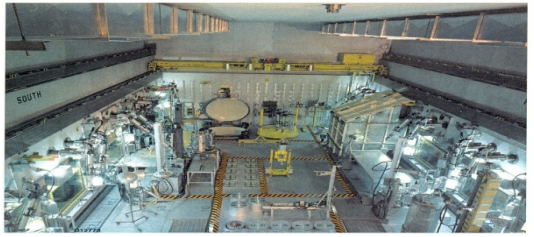
## Recent R&D Status (II)

### Remote operability and inter-connectivity

- Remote operability and maintainability improvements of unit pyroprocessing equipments with 3-D digital simulator, mock-up facility, and at PRIDE facility
- Material flow analysis between up- and down-process
- Integrated test of full-spectrum pyroprocessing system at PRIDE facility

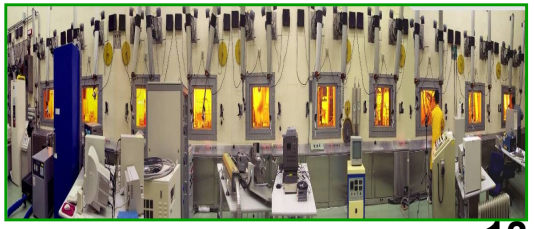
### Experience on spent-fuel test

- **Surrogates (DU and SimFuel) tests** with Lab-scale and PRIDE equipments
- **Spent fuel tests** with IRT(Integrated Recycling Test) at INL under JFCS
- **Coupling both test results** to get experiences on handling of spent fuel under Ar atmosphere and on design/operation of Ar hot-cell



### Minimization of HLW waste generation

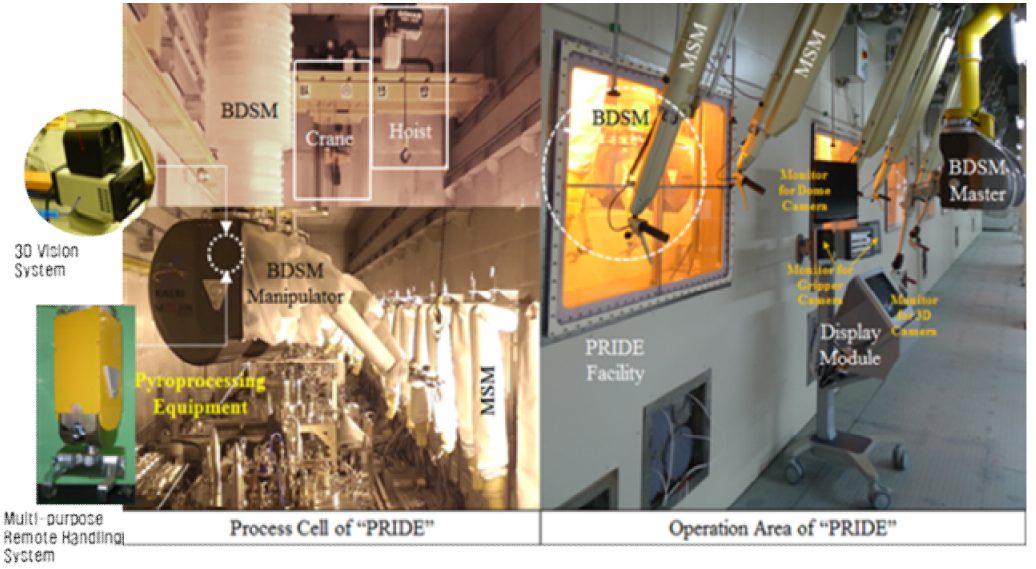
- Selective FPs (Cs,I etc.) capturing test at DFDF
- Removal of FPs from salt waste ➲ Recycling of purified salt
- Zr recovery from cladding hull and its reuse



# Pyroprocessing Development : PRIDE

## Engineering-scale Pyroprocessing development

- **PRIDE :** *PyRoprocessing Integrated inactive DEmonstration facility (10 ton-HM/yr)*
  - **Purpose**: Demonstration of full-spectrum pyroprocessing performance with depleted uranium and surrogate materials
  - **Milestones:** Design (‘07~’08), Installation (‘09~’12.6), Blank tests (‘12.7~)
  - **Operation:** Salt test (’13), DU test (’14), SimFuel(surrogate) test (‘15~‘16)
  - **Expectations**
    - Demonstration of Eng-scale integrated pyroprocessing facility with surrogates (DU and SimFuels)
    - Experiences in scale-up and in-cell remote handling systems and utilities
    - Securing commercialization technology in connection with JFCS results
    - Development of safeguard technology through cooperation with IAEA



# SFR System Development

## Objectives of a prototype SFR program

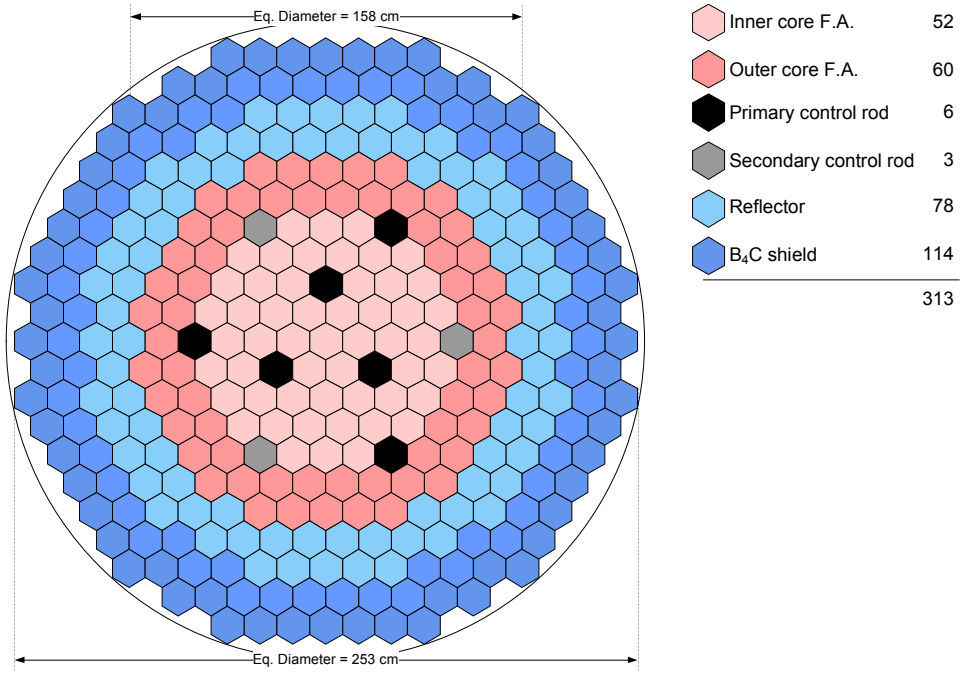
- Irradiation test of TRU fuels
- Acquisition of design, construction, and operation technologies

## Key milestones

- Preparation SAR for the application of design approval by 2017
- Design approval by 2020
- Construction of a prototype SFR by 2028

## Conceptual design

- NSSS design by KAERI (joint program with ANL)
- BOP design by Korean nuclear industries




<Core Configuration of Prototype SFR>

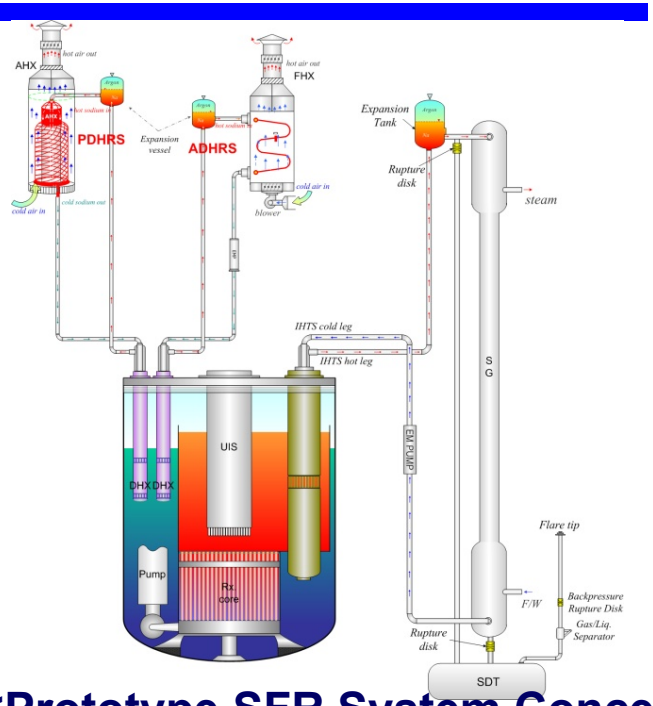
# SFR System Development – Cont'd

## Major design features

- Pool-type reactor
- Power : 150 Mwe
- Metallic fuel : U-Zr (initial core)
  → U-TRU-Zr (reload core)
- Transition from U core to TRU core
- Fluid system : PHTS, IHTS design
- Decay heat removal system : combination of
  2 passive + 2 active systems

## Recent R&D status

- Construction of sodium experimental facility (STELLA-1)
- Performance test of main component including heat exchangers and mechanical pump




<Prototype SFR System Concept>

<STELLA-1 Facility>

# Closing Remarks

- Public and stakeholder engagement program has been started to propose a national spent fuel management policy by the end of 2014.
- KAERI has full spectrum R&D activities for the efficient and systematic development of advanced nuclear fuel cycle
  - Transportation and long-term storage system for interim storage
  - Pyroprocessing-SFR system for spent fuel recycling
  - Advanced geological disposal system for HLW
  - DD&R for NPP
- Adopting Advanced Fuel Cycle coupled with Pyro and SFR is a promising strategy for resolving the issues of spent fuel management and nuclear energy resources.